Bemisia argentifolii (Homoptera: Aleyrodidae) Attacking Species of Medicinal Herbal Plants

ALVIN M. SIMMONS,[1] GLORIA S. MCCUTCHEON,[2] ROBERT J. DUFAULT,[2] RICHARD L. HASSELL,[2] AND JAMES W. RUSHING[2]

Ann. Entomol. Soc. Am. 93(4): 856–861 (2000)

ABSTRACT Research was conducted on the production potential of selected medicinal herbal plant species as new crops suitable for cultivation in South Carolina. Whiteflies (*Bemisia argentifolii* Bellows & Perring) were found in an experimental production field infesting five perennial species of medicinal herbal plants [feverfew, *Tanacetum parthenium* (L.) Schultz-Bipontinus; St. John's wort, *Hypericum perforatum* L.; purple coneflower, *Echinacea pallida* (Nuttall) Nuttall and *E. purpurea* (L.) Moench; and common valerian, *Valeriana officinalis* L.]. This article reports on whiteflies attacking and developing on these plant species. Density of whitefly nymphs was highest (mean = 2.3/cm^2) on the second fully expanded leaf on the apical meristem of *E. purpurea* as compared with the same leaf position on the other plant species where average whitefly density ranged from 0.1 to 0.6 nymphs per square centimeter from late November 1998 through January 1999. Similarly, adult capture on sticky cards was high (mean = 123 whiteflies per card) in plots of *E. purpurea* compared with plots of the other four species (mean = 8 to 20 whiteflies per card per species), and adult counts were elevated in the highest (440 kg N/ha) of three fertility rates in *E. purpurea.* Moreover, laboratory tests agreed with the observation of a higher population of *B. argentifolii* on *E. purpurea* compared with the other four plant species. The whitefly completed development on all five plant species, and whitefly-associated parasitoids emerged from field-leaf samples of each plant species.

KEY WORDS whitefly, *Bemisia argentifolii, Bemisia tabaci* biotype-B, parasitoid, plant host, fertility

WHITEFLIES ARE DESTRUCTIVE worldwide pests on many plant species of economic importance. *Bemisia argentifolii* Bellows & Perring has become a particularly problematic pest during the past decade (USDA 1997). Most whitefly-related research has focused on row, horticultural, and ornamental crops because of their economic importance. However, weed and other host species (Yassin and Bendixen 1982, Calvitti and Remotti 1998) have been examined as whitefly hosts because of associated plant pathogens and their potential impact on insect population dynamics. *B. argentifolii*, also called B-biotype *B. tabaci* (Gennadius) (Bellows et al. 1994, Brown et al. 1995), has a wide host range (Ghong 1969, Greathead 1986, Cock 1993). Although the *B. tabaci* A-biotype has been known in the United States for >100 yr, the B-biotype was first detected in the United States in the late 1980s (Schuster et al. 1990). The taxonomic status of the B-biotype is under debate among researchers; it may have species status (Perring et al. 1993) or it may be one of multiple biotypes worldwide (Brown et al. 1995). There have been several literature reviews of the host plants of *B. tabaci* that indicate that it feeds on ≈500 plant species (Azab 1970, Greathead 1986, Cock 1993). The host plant studies report activity of *Bemisia* in warm climatic zones of the globe, and include annual, perennial, woody, and herbaceous plant species.

Many herbal plant species have been used for medicinal purposes for centuries (Hobbs 1989a, Hahn 1992, Bombardelli and Morazzoni 1995). Beyond repellency and insecticidal activity, little research has been conducted on insect pests of many herbal plant species. There has not been any research reported on whiteflies on plant species in the families Hypericaeae and Valerianaceae. In the eastern United States, South Carolina is the northern geographic limit with year-round feral populations of *B. argentifolii* (Simmons and Esley 1995). *Bemisia* survives climates with mild winters on cultivated and wild plant species (Ohnesorge et al. 1981, Gerling 1984, Simmons and Elsey 1995). Over the past decade, consumers have been interested in medicinal herbs, and industry has been trying to respond to this need. This study was conducted to determine the vulnerability of five selected medicinal herbal plant species to *B. argentifolii* to help determine the potential pest problems facing the production of these new crops in South Carolina.

This article reports the results of research only. Mention of a proprietary product does not constitute an endorsement or recommendation by USDA or by Clemson University for its use.

[1] U.S. Vegetable Laboratory, USDA-ARS, 2875 Savannah Highway, Charleston, SC 29414.

[2] Coastal Research and Education Center, Clemson University, 2865 Savannah Highway, Charleston, SC 29414.

Table 1. List of new hosts of *B. argentifolii* from field infestation in Charleston, SC

Family	Species	Common name
Asteraceae	*Tanacetum parthenium* (L.) Schultz-Bipontinus[a]	Feverfew
	Echinacea pallida (Nuttall) Nuttall	Pallida, purple coneflower
	Echinacea purpurea (L.) Moench	Purpurea, purple coneflower
Hypericaeae	*Hypericum perforatum* L.[b]	St. John's wort
Valerianaceae	*Valeriana officinalis* L.	Common valerian

[a] Formerly *Chrysanthemum parthenium.*
[b] Some researchers place this in the family Guttiferae (Hobbs 1989b).

Materials and Methods

Field Tests. Five medicinal herbal plant species [feverfew, *Tanacetum parthenium* (L.) Schultz-Bipontinus; St. John's wort, *Hypericum perforatum* L.; purple coneflower, *Echinacea pallida* (Nuttall) Nuttall and *E. purpurea* (L.) Moench; and common valerian, *Valeriana officinalis* L.] were established in field plots on 14 July 1998. These species represent three families (Table 1), and they are marketed commercially for numerous medicinal purposes (Hobbs 1989a, 1989b; Bombardelli and Morazzoni 1995). Three fertilizer rates (in ratio 10:4.4:8.3 of nitrogen, phosphorus, and potassium, respectively) were used and consisted of 220, 330, or 440 kg N/ha per plot. The seedlings were first germinated in a whitefly-free greenhouse. The plant species were transplanted into plots (6 m long) per species in beds mulched with white plastic. Forty plants were established per plot with 30-cm spacing. Drip irrigation was used as needed. No pesticides were used in the production of the crops. The plots were set up in a split block design with location as main block and fertilizer treatments as subblocks. Plant species were randomized and replicated once within each fertilizer treatment.

Yellow sticky cards (16 cm^2, Olson, Medina, OH) were placed horizontally, 15 cm above row beds, and randomly located within each replicate on 18 November 1998. At about weekly intervals, the sticky cards were replaced with new cards. The last cards were retrieved 5 February 1999. Yellow sticky cards have been widely used for trapping whiteflies (Cohen and Marco 1973, Gerling and Horowitz 1984, Valdez and Wolfenbarger 1995), and they have been recently used for sampling for parasitoids of *Bemisia* (Simmons 1998, Simmons and Jackson 2000). The numbers of *B. argentifolii* and its associated parasitoids captured on the cards were determined with the aid of a microscope.

The second fully expanded true leaf on the apical meristem of plants of each species was collected approximately weekly for immature whitefly density and whitefly parasitism information. However, the top ≈8 cm stem (with leaves) of *H. perforatum* was collected for the leaf samples because of its small leaf size and atypical plant architecture. The number of nymphs on two leaves per plot on a given date was counted with the aid of a microscope and leaf area was determined with a leaf area meter (model 3000, LI-COR, Lincoln, NE). The number of nymphs was then divided by leaf area to calculate the number of nymphs per square centimeter. A separate two-leaf sample per plot was taken on each sample date and each was held in the laboratory in a closed carton (0.5 ml) for 3 wk. The numbers of adult *B. argentifolii* and its parasitoids (adults) were counted. Percent parasitism was based on the proportion of emerged parasitoids to emerged parasitoids and whiteflies.

Data were analyzed with the SAS (SAS Institute 1994). Main effects and multiple comparisons of treatment means for whitefly nymphs or adults, and parasitoids were analyzed using the PROC Mixed procedure. Percentages were transformed using arcsine transformation before the analysis, but the means are presented on back-transformed data.

Laboratory Tests. Plants of the five species were grown in the greenhouse in Jiffy Mix (composed of 1:1 Canadian sphagnum peat: vermiculite; Jiffy Products of America, Batavia, IL) for use in the laboratory tests. An open-choice test with all species was set up in a laboratory room (3.4 m long by 1.8 m wide by 2.1 m high). The walls, floor, and ceiling were light-to-medium brown. Three collard (*Brassica oleracea* ssp. *acephala* de Condolle) plants with greenhouse-reared adult and nymphal *B. argentifolii*, according to Simmons (1994), were placed at one end of the laboratory room. Leaves from the second fully expanded true leaf on the apical meristem of each species, except *H. perforatum* from which the top ≈8 cm stem with leaves, were placed in water and taken to the laboratory. Each plant sample was set up in a green floral water wick. The floral wicks with plant samples were inserted into the bottom end of 4 cm tall clear plastic cups. They were arranged in a completely randomized design in the above-mentioned room. Each was placed 13 cm apart, and the walls of the room were 34 cm from the nearest leaf samples. The number of adult whiteflies was counted on each plant sample after 24 h. The plant samples were examined with the aid of a microscope and the number of eggs was counted for each plant sample. Overhead florescent lighting (350 lux at leaf sample height) was used throughout the test. There were 10 trials with each plant species replicated six times per trial.

An additional test was carried out as a laboratory no-choice bioassay using petri dish cages (modification of illustration in Simmons 1994). Each arena was 2.20 cm deep with one 2.54-cm-diameter opening in the center of the bottom of the petri dish. The second fully expanded true leaf on the apical meristem of each test plant was placed on a water moistened filter paper in an inverted petri dish lid. The bottom of the petri dish was placed inside the lid and on top of the leaf so that the 2.54-cm opening served as the exposed test arena on the abaxial leaf surface. The basal portion of leaves was removed when a leaf could not fit into the petri dish. However, multiple stems with leaves of *H. perforatum* were used to fill the 2.54-cm-diameter test

area. An additional petri dish lid was placed on top of the petri dish. Through a small hole drilled in the center of the top lid, 15 female *B. argentifolii* (from the above mentioned colony) were introduced into each cage, and the entrance was plugged with cotton fiber. Six cages for each plant species were set up. These were held in an environmental chamber under constant dark condition and 25°C for 16 h. Three trials were conducted. The number of eggs deposited was counted with the aid of a microscope. Means and standard errors for whitefly eggs and adults were separated using the Student–Newman–Kuels test (SAS Institute 1994).

Results and Discussion

Field Tests. *B. argentifolii* nymphs and adults were collected from each of the five plant species. Each of these species represents new hosts in three families for *B. argentifolii* (Table 1). *T. parthenium* was formerly placed in the genus *Chrysanthemum*, which is in the large family of Asteraceae (formerly Compositae). Greathead (1986) listed 56 species as hosts to *B. tabaci* in this family including several in the genus *Chrysanthemum*, but not *C. parthenium.* In host surveys of *B. tabaci*, Tunc et al. (1983) and Khan et al. (1985) listed the genus *Chrysanthemum* as a host, but only one species was identified. *T. parthenium* is a well known plant, and it was used by the ancient Egyptians and Greeks for medicinal purposes (Hobbs 1989a). It is widely distributed in Europe, Asia, and Northern Africa, and is naturalized in North America (Bombardelli and Morazzoni (1994). Hence, we believe that Tunc et al. (1983) and Kahn et al. (1985) would have identified *T. parthenium* if it were among the species in their survey. Some researchers place *H. perforatum* in the family Guttiferae (Hobbs 1989b). In the review of hosts of *B. tabaci* by Greathead (1986), only one species, *Psorospermum corymbiferum* Hochreutiner, was listed in the family Guttiferae.

Plant species had a significant effect on whitefly adult capture ($F = 4.84$; df = 4, 425; $P < 0.0008$). The overall capture of adult *B. argentifolii* was greatest in the *E. purpurea* plots ($t = 5.18$, df = 58, $P < 0.0001$) compared with plots of either of the other four plant species, notably in early to mid-December (Fig. 1). The decline in adult capture in January apparently reflected the decline in plant condition and lower temperature. The abundance of green leaves was suppressed with the lower temperature in January. There was no overall significant fertilizer effect. However, there was a significant interaction ($F = 1.93$; df = 8, 425; $P = 0.05$) between plant species and fertility. The plant species effect occurred for *E. purpurea* at the 440 kg N/ha fertility rate where all of the 14 treatment comparisons were highly significant (Table 2). Comparisons of the adult whitefly counts for any other combination of plant species and fertility rates were not statistically ($P > 0.05$) significant.

The average density of whitefly nymphs on the second leaf position from the top of the plant ranged from 0 to 2.3/cm^2 leaf over time on the plants (Fig. 2).

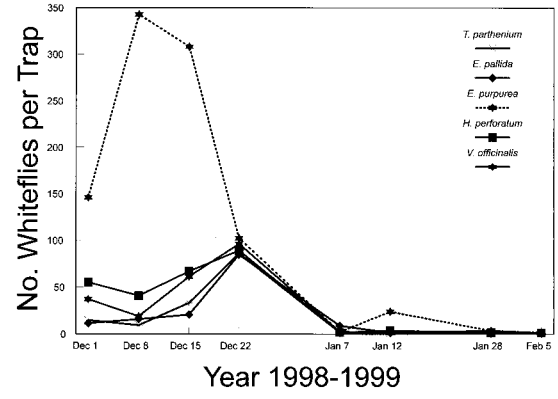

Fig. 1. Mean number of *B. argentifolii* collected on yellow sticky cards in plots of five medicinal herbal species in field in Charleston, SC, November 1998–February 1999.

There was a significant plant species effect on density of whitefly nymphs ($F = 22.56$; df = 4, 381; $P < 0.0001$). The overall effect on nymphal density was primarily from *E. purpurea* ($t = 7.69$, df = 22, $P < 0.0001$) and secondarily from *E. pallida* ($t = 2.60$, df = 22, $P < 0.0166$) compared with the other species. There was no significant effect on nymphal densities from any of the other species. Also, no fertility effect ($F = 0.44$; df = 2, 9; $P = 0.66$) was observed on nymphal density. On some of the plant species such as *E. purpurea*, we noticed higher densities of immatures on lower leaves than on the sampled leaf. However, the second leaf position was selected for sampling instead of older leaves to minimize any influence of different plant growth rates on whitefly abundance. The abundance of whiteflies on *E. purpurea* is a relatively high density for *B. argentifolii* in the coastal area of South Carolina

Table 2. Comparison of differences of whitefly abundance on sticky cards for the high fertility treatment of *Echinacea* purpurea against all possible combinations of fertility treatments of five herbal medicinal species

Plant species	Fertility (kg N/ha)	Differences from *E. purpurea* at 440 kg N/ha and *P* levels	
		No. of adults	*P* value
T. parthenium	220	243.2	0.0001
E. pallida	220	252.5	0.0001
E. purpurea	220	188.3	0.0026
H. perforatum	220	225.2	0.0001
V. officinalis	220	246.0	0.0003
T. parthenium	330	241.9	0.0001
E. pallida	330	240.6	0.0001
E. purpurea	330	214.3	0.0006
H. perforatum	330	226.2	0.0003
V. officinalis	330	245.3	0.0003
T. parthenium	440	236.8	0.0001
E. pallida	440	231.8	0.0001
H. perforatum	440	233.7	0.0001
V. officinalis	440	220.2	0.0001

Differences for the number of adults are from sticky card counts; for each comparison, the whitefly count is greater for *E. purpurea* at 440 kg N/ha. Probabilities for significance (*P*) are based on the Proc Mix procedure (SAS Institute 1994).

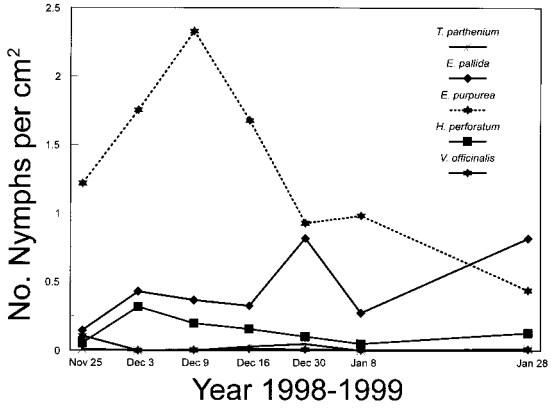

Fig. 2. Mean number of *B. argentifolii* nymphs on the second fully expanded true leaf on the apical meristem of plants of each of four plant species, and leaves of the upper 8 cm stem of *Hypericum perforatum*, in field in Charleston, SC, for different dates from November 1998 to January 1999.

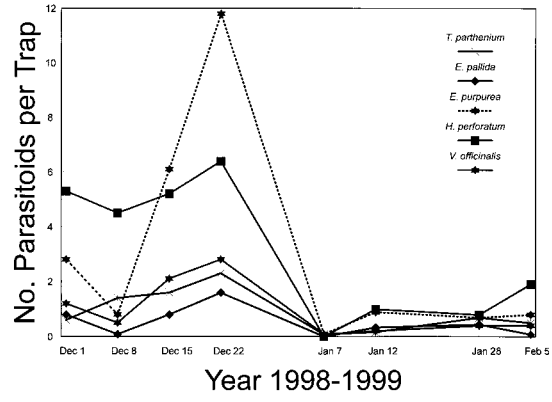

Fig. 3. Mean number of parasitoids of *B. argentifolii* collected on yellow sticky cards in plots of five medicinal herbal species in field in Charleston, SC, November 1998 to February 1999.

for the winter season (Simmons and Elsey 1995; A.M.S., unpublished data). In coastal South Carolina, the abundance of *B. argentifolii* is highest during the summer and fall. During a 10-wk summer study on 10 vegetables, including cucurbits, which are among the most preferred hosts, mean densities of nymphs and eggs ranged from nearly 0 to 15/cm^2 leaf but was generally <3 immatures per square centimeter of leaf (Simmons 1994). On *E. purpurea*, the mean density of nymphs per leaf peaked at 2.3/cm^2 (mean = 72 nymphs per leaf) during the third week and was a low of 0.5/cm^2 (mean = 11 nymphs per leaf) during the last sampling date (Fig. 2). We observed whitefly pupal exuviae on all five species. Among the five plant species in this study, only *H. perforatum* has glabrous leaves. Researchers have reported that glabrousness is a plant trait associated with reduced whitefly abundance (DePonti et al. 1990).

The only significant ($F = 12.25$; df = 4, 427; $P < 0.0001$) treatment effect for parasitoid capture was for plant species. More parasitoids were captured from *E. purpurea* and *H. perforatum* compared with the other species from late November to late January (Fig. 3). The captured parasitoids were primarily *Eretmocerus* spp. (≈55%) and *Encarsia pergandiella* Howard (≈45%). There was no overall plant species effect for percentage parasitism ($F = 1.6$; df = 4, 52; $P > 0.19$) (Fig. 4A), and there was no fertility effect ($F = 0.90$; df = 2, 16; $P > 0.43$). Few adult whiteflies and parasitoids were collected from the leaf samples (Fig. 4B). This relative abundance is consistent with results from the sticky trap data (Fig. 1). There was a plant species effect on parasitoid emergence from the leaf samples ($F = 3.96$; df = 4, 392; $P < 0.0036$), which resulted from *E. purpurea* ($t = 5.02$, df = 116, $P < 0.0001$). Likewise, there was a plant species effect on whitefly emergence from the leaf samples ($F = 7.73$; df = 4, 292; $P < 0.0001$), which resulted from a relatively high emergence from *E. pupurea* ($t < 5.49$, df = 41, $P < 0.0001$). Moreover, in concert with the sticky trap counts (Table 2), there was an interaction effect on whitefly emergence for plant species and fertility. Whitefly counts for the highest fertility rate (440 kg N/ha) of *E. pupurea* was significantly ($P < 0.05$) higher than for all other plant species and fertility rate combinations.

Laboratory Tests. In the open-choice laboratory test, the densities of adult whiteflies ($F = 6.74$; df = 4,

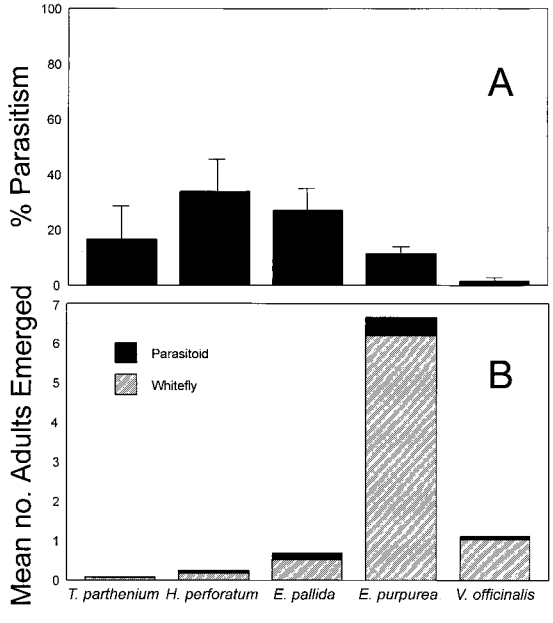

Fig. 4. (A) Percentage parasitism of *B. argentifolii* ($F = 1.60$; df = 4, 52; $P = 0.19$) and (B) mean number of emerged whiteflies ($F = 7.73$; df = 4, 392; $P < 0.0001$) and mean number of emerged parasitoids ($F = 3.96$; df = 4, 392; $P < 0.004$) from leaf of second leaf position from the top of five medicinal herbal plant species in field in Charleston, SC, November 1998 to January 1999; statistics according to the PROC Mix procedure (SAS Institute 1994).

Table 3. Abundance of whiteflies, *B. argentifolii*, and oviposition (mean ± SEM) on herbal medicinal plants in an open-choice laboratory test during 24 h

Plant species	No. insects		Leaf area/cm^2 (SEM)	No. insects/cm^2	
	Eggs	Adults		Eggs	Adult
T. parthenium	14.8 ± 3.6b	13.4 ± 3.0b	9.6 ± 0.50c	2.0 ± 0.52ab	1.5 ± 0.38b
E. pallida	9.6 ± 2.1b	21.4 ± 4.7b	13.9 ± 0.44b	0.7 ± 0.14b	1.4 ± 0.25b
E. purpurea	68.4 ± 13.8a	56.6 ± 10.3a	15.0 ± 0.73ab	4.6 ± 0.81a	3.8 ± 0.65a
H. perforatum	50.2 ± 10.5a	32.5 ± 7.2b	11.1 ± 0.40c	4.8 ± 1.10a	2.9 ± 0.63ab
V. officinalis	48.4 ± 12.0a	71.2 ± 10.9a	16.1 ± 0.61a	3.5 ± 1.08a	4.7 ± 0.75a

Means within a column and followed by different letters are significantly different ($P < 0.05$) according to Student–Newman–Kuels test (SAS Institute 1994).

183; $P < 0.0001$) and eggs ($F = 4.82$; df = 4, 182; $P < 0.001$) varied among the plant species (Table 3). The overall abundance and densities of eggs and adults were fewest on *T. parthenium* and *E. pallida.* Although the counts and densities were statistically similar on *E. purpurea*, *H. perforatum*, and *V. officinalis*, the ranking of the abundance of the insects tended to be highest on *E. purpurea.* Even though it was desirable to test leaves of the same size among plant species, because of plant phenotype disparities, this parameter was not constant (Table 3). However, no trend was evident between whitefly abundance and leaf area. For example, whitefly abundance differed between *E. pallida* and *E. purpurea* although these two species had the same leaf area. The gender of the whiteflies on the different plants was not determined, but we suspect that the ratio may have been similar among the plant species. Also, it is not known if crowding could have affected oviposition. During each 24-h trial, the whiteflies had an opportunity to find and accept or reject leaves of each species.

Results from the no-choice test (Table 4) are in general agreement with the free-choice test. All plant species were acceptable for oviposition, and relatively few eggs were oviposited on *T. parthenium* and *E. pallida.* Conversely, the highest number of eggs was on *E. purpurea* and *V. officinalis.* However, the results on *H. perforatum* in the no-choice test deviated from the relative ranking in the free-choice test. In the no-choice test, with the exception of *H. perforatum*, the leaves completely covered the test area. Hence, there may have been at least a slight underestimation of the relative oviposition on *H. perforatum* compared with the other plant species. Although multiple *H. perforatum* stems were used, space still existed within the 2.54-cm-diameter test area of the petri dish.

Table 4. Number (mean ± SEM) of *B. argentifolii* eggs on leaves of herbal medicinal plants in a no-choice laboratory test after 16 h exposure

Plant species	No. eggs/cm^2
Tanacetum parthenium	4.9 ± 1.19b
Echinacea pallida	1.9 ± 0.54b
Echinacea purpurea	9.8 ± 1.73a
Hypericum perforatum	4.1 ± 0.88b
Valeriana officinalis	9.7 ± 1.80a

Means followed by different letters are significantly different ($F = 7.06$, df = 4, 85; $P < 0.001$) according to Student–Newman–Kuels test (SAS Institute 1994).

In conclusion, all five herbal medicinal plant species were hosts for *B. argentifolii*, supporting feeding, oviposition, and development to the adult stage. Different population levels of the whiteflies were observed among these five plant species, and high fertility exacerbated the whitefly infestation on *E. purpurea.* Aphelinid parasitoids attacked whiteflies on these plant species. These perennial plants can help support overwintering populations of *B. argentifolii* in a mild climate. In addition, the commercial use of these plants dictates restrictions on the use of traditional insecticides. Hence, biological control may be an appealing tool for use in a pest management system on these herbal medicinal crops.

Acknowledgments

We thank Julie Day, Holly Moore, and Robert Green for their technical support. We appreciate the comments and reviews of the manuscript by S. Kris Braman (University of Georgia), Larry D. Godfrey (University of California), and B. Merle Shepard (Clemson University).

References Cited

Azab, A. K. 1970. On the range of host-plants of *Bemisia tabaci* (Genn.). Bull. Soc. Entomol. Egypt 54: 319–326.

Bellows, Jr., T. S., T. M. Perring, R. J. Gill, and D. H. Headrick. 1994. Description of a species of *Bemisia* (Homoptera: Aleyrodidae). Ann. Entomol. Soc. Am. 81: 195–206.

Bombardelli, E., and P. Morazzoni. 1995. *Hypericum perforatum.* Fitoterapia 66(1): 43–68.

Brown, J. K., D. R. Frohlich, and R. C. Rosell. 1995. The sweetpotato or silverleaf whiteflies: biotypes of *Bemisia tabaci* or a species complex? Annu. Rev. Entomol. 40: 511–534.

Calvitti, M., and P. C. Remotti. 1998. Host preference and performance of *Bemisia argentifolii* (Homoptera: Aleyrodidae) on weeds in central Italy. Environ. Entomol. 27: 1350–1356.

Cock, M.J.W. 1993. *Bemisia tabaci* an update 1986–1992 on the cotton whitefly with an annotated bibliography. CAB, Ascot, UK.

Cohen, S., and S. Marco. 1973. Reducing the spread of aphid-transmitted viruses in peppers by trapping the aphids on sticky polyethylene sheets. Phytopathology 63: 1207–1209.

DePonti, O.M.B., L. R. Romanow, and M. J. Berlinger. 1990. Whitefly-plant relationships: plant resistance, pp. 91–106. *In* D. Gerling [ed.], Whiteflies: their bionomics, pest status, and management. Intercept, Andover, Hants, UK.

Gerling, D. 1984. The overwintering mode of *Bemisia tabaci* and its parasitoids in Israel. Phytoparasitica 12: 109–118.

Gerling, D., and A. R. Horowitz. 1984. Yellow traps for evaluating the population levels and dispersal patterns of *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae). Ann. Entomol. Soc. Am. 77: 753–759.

Ghong, Y. 1969. Host plant morphological variation of *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) in Taiwan. Plant Prot. Bull. (Taiwan) 2: 23–32.

Greathead, A. H. 1986. Host plants, pp. 17–25. *In* M.J.W. Cock [ed.], *Bemisia tabaci*—a literature survey on the cotton whitefly with an annotated bibliography. CAB, Ascot, UK.

Hahn, G. 1992. *Hypericum perforatum* (St. John's Wort)—a medicinal herb used in antiquity and still of interest today. J. Naturopath. Med. 1(3): 94–96.

Hobbs, C. 1989a. Feverfew *Tanacetum parthenium:* a review. HerbalGram 20(spring): 26–36.

Hobbs, C. 1989b. St. John's Wort *Hypericum perforatum.* Herbalgram 18/19: 24–33.

Khan, A. G., A. A. Goraya, A. I. Mohyuddin, and C. Inayatullah. 1985. The whiteflies (Homoptera: Aleyrodidae) of Pakistan. Pak. J. Zool. 17: 29–33.

Ohnesorge, B., N. Sharaf, and T. Allawi. 1981. Population studies on the tobacco whitefly *Bemisia tabaci* Genn. (Homoptera: Aleyrodidae) during the winter season. II. Some mortality factors of the immature stages. Z. Angew. Entomol. 92: 127–136.

Perring, T. M., A. D. Cooper, R. J. Rodriguez, C. A. Farrar, and T. S. Bellows, Jr. 1993. Identification of a whitefly species by genomic and behavioral studies. Science 259: 74–77.

SAS Institute. 1994. SAS/STAT user's guide, version 6, 4th ed. SAS Institute, Cary, NC.

Schuster, D. J., T. F. Mueller, J. B. Kring, and J. F. Price. 1990. Relationship of the sweetpotato whitefly to a new tomato disorder in Florida. HortScience 25: 1618–1620.

Simmons, A. M. 1994. Oviposition on vegetables by *Bemisia tabaci* (Homoptera: Aleyrodidae): temporal and leaf surface factors. Environ. Entomol. 23: 382–389.

Simmons, A. M. 1998. Survey of the parasitoids of *Bemisia argentifolii* (Homoptera: Aleyrodidae) in coastal South Carolina using yellow sticky traps. J. Entomol. Sci. 33: 7–14.

Simmons, A. M., and K. D. Elsey. 1995. Overwintering and cold tolerance of *Bemisia argentifolii* (Homoptera: Aleyrodidae) in coastal South Carolina. J. Entomol. Sci. 30: 497–506.

Simmons, A. M., and D. M. Jackson. 2000. Evaluation of foliar applied insecticides on abundance of parasitoids of *Bemisia argentifolii* (Homoptera: Aleyrodidae) in vegetables. J. Entomol. Sci. 35: 1–8.

Tunc, A., N. Turhan, A. H. Belli, A. Kismir, and N. Kisakurek. 1983. Cukurova bolgesinde beyaz sinek (*Bemisia tabaci* Genn.) in kisi gecirme durumu ve konukcularinin tesbiti uzefinde arastirmalar. Bitki Koruma Bulteni CILT 23: 42–52.

Valdez, J. A., and D. A. Wolfenbarger. 1995. Yellow traps and insecticides for control of a strain of sweet potato whitefly and associated virus incidence on pepper. J. Entomol. Sci. 30: 342–348.

[USDA] U. S. Department of Agriculture. 1997. Silverleaf whitefly: 1997. *In* T. J. Henneberry, N. Toscano, R. M. Faust, and D. Koop [eds.], Five-year national research and action plan: progress review, technology transfer and new research and action plan (1997–2001). U.S. Dep. Agric. Agric. Res. Serv. Publ. 1997–02 (suppl.).

Yassin, M., and L. E. Bendixen. 1982. Weed hosts of the cotton whitefly (*Bemisia tabaci* (Genn.)) Homoptera: Aleyrodidae. Res. Bull. Ohio Agric. Res. Dev. Cent. 1144.

Received for publication 17 December 1999; accepted 21 February 2000.